A RESEARCH PROGRAM IN LOGISTICS SYSTEMS

Final Report

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Gainesville, Florida 32611

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The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Inventory control; Reliability; Facility location, Non-linear programming; Scheduling; Stochastic processes

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This proposal covered a three year research program in logistics systems and complemented research which was already in progress under contract number DAH C04-68C-0002 and Grant DA-ARO-D-31-124-70-G92. The on-going contract provided supplementary support for graduate research assistants, secretarial support, travel, and publication costs.

The project was performed through the College of Engineering under the general supervision and guidelines of the Engineering and Industrial Experiment station, and administered through the University of Florida's Office of

STATEMENT OF PROBLEMS STUDIED

The problems studied were a variety of areas affecting logistics management. Examples include special inventory problems, scheduling activities, transportation and distribution problems. Reliability and maintainability models as well as assembly line problems in a stochastic environment were also considered. Finally nonlinear optimization problems were also addressed with application to facility location and design and test range instrumentation location.

All of the above mentioned problems directly affect the operation of a logistics system. For example the location of supply depots is a crucial question and the work in facility design and location provides useful insights. Distribution problems and scheduling resources on scarce transportation is another problem which often faces the logistics manager. A perusal of the reports which are referenced herein indicate the variety of problems studied.

SUMMARY

This proposal covered a three year research program in logistics systems and complemented research which was already in progress under contract number DAH C04-68C-0002 and Grant DA-ARO-D-31-124-70-G92. The on-going contract provided supplementary support for graduate research assistants, secretarial support, travel, and publication costs.

The project was performed through the College of Engineering under the general supervision and guidelines of the Engineering and Industrial Experiment Station, and administered through the University of Florida's Office of Sponsored Research.

1. Journal Papers

A. Manuscripts Submitted

"Decomposition of the Group Problem in Integer Programming," to Mathematical Programming by G. Hefley and M. E. Thomas.

"A Minimax Facility Configuration Problem Involving Lattice Points," by R. L. Francis, (submitted to Operations Research and recommended for publication subject to revisions).

"A Network Flow Solution to a Multifacility Minimax Location Problem Involving Rectilinear Distances," by P. M. Dearing and R. L. Francis, submitted to Operations Research, October, 1972.

"Equivalence of Redundant Systems with Respect to Time to Failure," by E. J. Muth, submitted to IEEE Transactions on Reliability.

"A Network Flow Solution to a Multi-Facility Minimax Location Problem Involving Rectilinear Distances," by P. M. Dearing and R. L. Francis, submitted to Transportation Science.

"A One Facility Minimax Location Problem Involving Rectilinear Distances," by P. M. Dearing and R. L. Francis, submitted to SIAM Journal.

"The Minimum Sphere Covering a Convex Polyhedron," by D. W. Hearn and J. Elzinga, submitted to Naval Research Logistics Quarterly, November, 1972.

"Analysis of Closed-Loop Conveyor Systems, The Discrete Flow Case," by E. J. Muth, submitted to AIIE Transactions.

"Moments Expressed in Terms of the Hazard Function and Applications," by E. J. Muth, submitted to Operations Research.

"Finding the N most Vital Links in Flow Networks," by H. D. Ratliff, G. T. Sicilia, and S. H. Lubore, submitted to Management Science.

"A Network Approach to a Multi-Facility, Multi-Product Production Scheduling Problem Without Backordering," by R. C. Dorsey, T. J. Hodgson, and H. D. Ratliff, submitted to Management Science.

"A Network Approach to a Multi-Facility Production Scheduling Problem with Backordering," by R. C. Dorsey, T. J. Hodgson, and H. D. Ratliff, submitted to Operations Research.

"An Efficient Integer Programming Algorithm for a Multi-Facility, Multi-Product Production Scheduling Problem," by R. C. Dorsey, T. J. Hodgson, and H. D. Ratliff, submitted to Management Science.

"A Multiple Facility, Multiple Product Production Scheduling Problem with Overtime," by R. C. Dorsey, T. J. Hodgson, and H. D. Ratliff, submitted to Canadian Journal of Operations Research and Information Processing.

"The Transient and Steady State Distribution of a Continuous Review (s, S) Inventory System with Arbitrary Interarrival Distribution Between Unit Demand," by B. D. Sivazlian, submitted to Operations Research.

"Hysteresis Effect in Discounted Replacement Problems," by J. F. Brown and B. D. Sivazlian, submitted to Naval Research Logistics Quarterly.

"An Optimum Multiple-Launch Program for Artificial Satellites," by B. D. Sivazlian, submitted to Opsearch.

"The Inversion of Two-Dimensional Laplace Transforms Using Digital and Analog Computers," by B. D. Sivazlian and P. E. Valisalo, submitted to Proceedings of the 7th AICA Congress, Prague, Czechoslovakia.

"Minimax Multifacility Location with Euclidean Distances," by J. Elzinga, D. Hearn, and W. D. Randolph, submitted to Transportation Science, Gugust, 1973.

"Decomposition of the Group Problem in Integeger Programming," by G. L. Hefley and M. E. Thomas, submitted to Mathematical Programming, August, 1973.

"A Minimax Layout Problem on the Line Involving Distances Between Classes of Objects," by R. L. Francis and R. L. Papineau, submitted to AIIE Transactions, August, 1973.

"Modeling and System Analysis of Multistation Closed-Loop Conveyors," E. J. Muth, submitted to International Journal of Production Research.

"A Survey of the State of the Art in Dynamic Programming," M. E. Thomas, submitted to AIIE Transactions.

"Activity Assignment on the Line - A Minisum Approach," T. J. Lowe, submitted to AIIE Transactions.

"Scheduling Vehicles Loads Under Certain Fixed Routing Assumptions." L. A. Martin-Vega and H. D. Ratliff, submitted to Management Science.

1. Journal Papers

B. Manuscripts Published

"The Minimum Covering Sphere Problem," By D. W. Hearn and J. Elzinga, Management Science:Theory, Vol. 19, No. 1, September, 1972, pp. 94-104.

"Geometrical Solutions for Some Minimax Location Problems," by D. W. Hearn and J. Elzinga, Transportation Science, Vol. 6, No. 4, November, 1972, pp. 379-394.

"A Minimax Facility Configuration Problem Involving Lattice Points," by R. L. Francis, Operations Research, Vol. 21, No. 1, 1973.

"A Note on a Minimax Location Problem," by D. W. Hearn and J. Elzinga, Transportation Science, Vol. 7, No. 1, February, 1973.

"The Production Rate of a Series of Work Stations with Variable Service Time," by E. J. Muth, The International Journal of Production Research, Vol. 11, No. 2, April 1973, pp. 155-169.

"Minimal Cost Cut Equivalent Networks," by J. C. Picard and H. D. Ratliff, Management Science: Theory, Vol. 19, No. 9, May 1973.

"Duality Relationships for a Nonlinear Version of the Generalized Neyman-Pearson Problem," by R. L. Francis and H. D. Meeks, Journal of Optimization Theory and Application, Vol. 11, No. 4, 1973, pp. 366-378.

"Expected Value and Variance of Failure Time in Redundant Systems," by E. J. Muth, IEEE Transactions on Reliability, Vol. R-22, No. 2, June 1973, pp. 103-105.

"Hyperbolic Integer Programming," by M. Grunspan and M. E. Thomas, Naval Research Logistics Quarterly, Vol. 20, No. 2, June 1973.

"Laplace Transforms for the Two-Unit Cold-Standby Redundant System," by D. G. Linton and R. N. Braswell, IEEE Transactions, R-22, No. 2, June 1973, pp. 105-108.

"The Inversion of Two-Dimensional Laplace Transforms Using Digital and Analog Computers," by B. D. Sivazlian and P. E. Valisalo, Proceedings of the Seventh International Analogue Computation Meetings, Conference on Hybrid Computation, Part 1, August 1973, pp. 90-93.

"Equivalence of Redundant Systems with Respect to Time to Failure," by E. J. Muth, IEEE Transactions on Reliability, Vol. R-22, No. 4, Oct. 1973, pp. 238-239.

"Location Theory: A Selective Bibliography," by R. L. Francis and J. M. Goldstein, Operations Research, 22, (1974) pp. 400-410. (A Technical Note.

"Computational Aspects of a Dual Algorithm for Quadratically Constrained Quadratic Programming," by D. W. Hearn, Proceedings of the ACM Annual Conference, Atlanta, Georgia, Aug., 1973.

"A Network Flow Solution to a Multifacility Minimax Location Problem Involving Rectilinear Distances," by P. M. Dearing and R. L. Francis, Transportation Science, Vol. 8, No. 2, May, 1974.

"Analysis of Closed-Loop Conveyor Systems, the Discrete Flow Case," by E. J. Muth, AIIE Transactions, Vol. 6, No. 1, March 1974, pp. 73-83.

TECHNICAL REPORTS PUBLISHED

The following research reports have been supported in part under Army Research Office and/or Office of Naval Research, Department of Industrial and Systems Engineering, University of Florida.

"On Some Minimax Location Problems Using Rectilinear Distance", by P.M. Dearing, Jr., and R.L. Francis, Research Report No. 68, September, 1972.

"Finding the N Most Vital Links in Flow Networks", by H.D. Ratliff, G.T. Sicilia, and S.H. Lubore, Research Report No. 73-1, January, 1973.

"Matrix Formulation and Solution of Conveyor Flow Problems", by Eginhard J. Muth, Research Report No. 73-2, January, 1973.

"A Solution Procedure for a Retilinear Distance Minimax Round Trip Location Problem", by Albert W. Chan and Donald W. Hearn, Research Report No. 73-3, January, 1973.

"Modeling Mining Attrition Using Networks with Gains", by P. McWhite and H.D. Ratliff, Research Report No. 73-4, January, 1973.

"A Network Approach to a Multi-Facility, Multi-Product Production Scheduling Problem Without Backordering", by Dorsey, Hodgson, and Ratliff, Research Report No. 73-5 , January, 1973.

"A Network Approach to a Multi-Facility, Multi-Product Production With Backordering", by Dorsey, Hodgson, and Ratliff, Research Report No. 73-6, January, 1973.

"A Multiple Facility, Multiple Product Production Scheduling Problem With Overtime *", by Robert C. Dorsey, Thom J. Hodgson, and H. Donald Ratliff, Research Report No. 73-7, January, 1973.

"An Efficient Integer Programming Algorithm for a Multi-Facility, Multi-Production Scheduling Problem*", by Robert C. Dorsey, Thom J. Hodgson, and Donald Ratliff, Research Report No. 73-8, January 1973.

"A Shop Model for a Naval Air Rework Facility", Christopher Haas and Thom J. Hodgson, Research Report No. 73-9, January 1973.

"Analysis for a Naval Air Rework Facility (NARF) One-for-One Exchange Inventory and Repair System", by Christopher Hass and Thom J. Hodson, Research Report No. 73-10,August 1973.

"A Minimax Layout Problem on the Line Involving Distances Between Classes of Objects*", by Richard L. Francis and Robert L. Papineau, Research Report No. 73-11, July, 1973.

"Allocation of Mine Countermeasures Resources When Shipping Flow is Fixed", by P.B. McWhite and H.D. Ratliff, Research Report No. 73-12, August, 1973.

"A Minimax Multifacility Location with Euclidean Distances", by Jack Elzinga, Donald Hearn, and W.D. Randolph, Research Report No. 73-13, July, 1973.

"A Minimax Location Problem on a Network", by P.M. Dearing and R.L. Francis, Research Report No. 73-14, September, 1973.

"Dual Approaches to Quadratically Constrained Quadratic Programming," by Donald Hearn and W. D. Randolph, Research Report No. 73-15, September, 1973.

"A Minimax Planar Facility Layout Problem," by Richard L. Francis and Robert L. Papineau, Research Report No. 74-1, January, 1974.

"Defending a Logistics System Under Mining Attack," Peter Bartow McWhite and H. Donald Ratliff, Research Report No. 74-2, February, 1974.

"Moments Expressed in Terms of the Hazard Function and Applications," by Eginhard J. Muth, Research Report No. 74-3, April, 1974.

"The Generalized Market Area Problem," by Timothy J. Lowe, and Arthur P. Hurter, Research Report No. 74-4, April 1974.

"A Weighted Round-Trip Location Problem," by Albert W. Chan and Donald w. Hearn, Research Report No. 74-5, June, 1974.

"Minimum Cuts and Related Problems," Jean-Claude Picard and H. Donald Ratliff, Research Report No. 74-6, May, 1974.

"A Round-Trip Location Problem on a Tree Graph," by Albert W. Chan and Richard L. Francis, Research Report No. 74-7, June, 1974.

"Activity Assignment on the Line - A Minisum Approach," by T. J. Lowe, Research Report No. 74-8, August, 1974.

"Microcomputer Control of Industrial Process," by Donald Hearn and Jesus Saenz, Research Report No. 74-9, August, 1974.

"Min-Max Deployment Problems," L. A. Martin-Vega and H. D. Ratliff, Research Report No. 74-10, August, 1974.

"A Facility Layout Problem Involving Lattice Points," Richard L. Francis and Albert W. Chan, Research Report No. 74-11, August, 1974.

"Convex Location Problems on Tree Networks," by P. M. Dearing, R. L. Francis and T. J. Lowe, Research Report No. 74-12, September, 1974.

"Modeling and System Analysis of Multistation Closed-Loop Conveyors," by Eginhard J. Muth, Research Report No. 75-1, February, 1975.

"A Minimax Facility Layout Problem Involving Distances Within and Between Facilities," by R. L. Francis, J. J. Bartholdi, and R. L. Papineau, Research Report No. 75-2, April, 1975.

"Scheduling Rules for a Class of Fixed Route Freight Scheduling Problems," Louis A. Martin-Vega, and H. Donald Ratliff, Research Report No. 75-3, June, 1975.

"Minimax Multifacility Location with Euclidean Distances," (Revised), by Jack Elzinga, Donald Hearn, W. D. Randolph, Research Report No. 75-4, June, 1975.

2. SCIENTIFIC PERSONNEL SUPPORTED BY ARO

A. Professors

R. L. Francis
E. J. Muth
D. W. Hearn
T. J. Lowe
H. D. Ratliff
B. D. Sivazlian

B. Students

W. D. Randolph, Ph.D. 6/74
R. C. Dorsey, Ph.D. 3/73
A. W. Chan, Ph.D. 8/74
S. Lakshminarayan, M.E. 12/74
J. J. Bartholdi III, M.S. 6/73
F. L. Nordai, M.S. 12/74
K. T. Nguyen
L. A. Martin-Vega, Ph.D. 3/75
C. H. Choi, M.S. 6/75

SUPPLEMENTARY NOTES

A. Meetings, Papers Presented and Seminars

Name of Meeting: TIMS International Conference
Location: Los Angeles, California
Author: Robert N. Braswell and F. M. Allen
Subject: Non-parametric Sensitivity Analysis in Linear Programming
Date: Fall, 1971

40th National ORSA Meeting
Anaheim, California
E. J. Muth
A General Analysis of Closed-Loop Conveyor Systems
October 27-29, 1971

40th National ORSA Meeting
Anaheim, California
E. J. Muth
On Ap!lications of the Root Locus Method in Operations Research
October 27-29, 1971

40th National ORSA Meeting
Anaheim, California
E. J. Muth
The Production Rate of a Series of Work Stations with Variable Service Times
October 27-29, 1971

41st National ORSA Meeting
New Orleans, La.
R. N. Braswell and J. A. Marban
Necessary and Sufficient Conditions for the Inequality Constrained Optimization Problem Using Directional Derivatives
April 26-28, 1972

41st National ORSA Meeting
New Orleans, La.
R. N. Braswell and T. Clark Pewitt
Generalizations of a Class of Frequency Functions
April 26-28, 1972

41st National ORSA Meeting
New Orleans, La.
B. D. Sivazlian
On Some Discounted Replacement Problems with Arbitrary Repair Time Distribution
April 26-28, 1972

Name of Meeting:	41st National ORSA Meeting
Location:	New Orleans, La.
Author:	E. J. Muth
Subject:	Closed Loop Conveyor Systems with Discrete Material Flow
Date:	April 26-28, 1972

41st National ORSA Meeting
New Orleans, La.
H. D. RAtliff and Jean-Claude Picard
A Graph Theoretic Equivalence for Integer Programs
April 26-28, 1972

41st National ORSA Meeting
New Orleans, La.
R. L. Francis
Properties of a Multifacility Location Problem Involving Euclidean Distances
April 26-28, 1972

41st National ORSA Meeting
New Orleans, La.
T. Goswick and B. D. Sivazlian
The Mixed Ordering Policy in Periodic Review Stochastic Multi-Commodity Inventory Systems
April 26-28, 1972

41st National ORSA Meeting
New Orleans, La.
M. E. Thomas and G. L. Hefley
Decomposition of the Group Problem
April 26-28, 1972

Joint Meeting of AIIE/ORSA/TIMS
Atlantic City, N.J.
Robert N. Braswell and D. G. Linton
Some Advancements in Reliability Theory for Systems with Standbys
November 8-10, 1972

Joint Meeting of AIIE/ORSA/TIMS
P. M. Dearing and R. L. Francis
A Network Flow Solution to a Multifacility Minimax Location Problem Using Rectilinear Distances
November 8-10, 1972

Joint Meeting of AIIE/ORSA/TIMS
Atlantic City, N.J.
R. L. Francis
A Minimax Lattice Point Location Problem
November 8-10, 1972

Name of Meeting:	Joint Meeting of AIIE/ORSA/TIMS
Location:	Atlantic City. N. J.
Author:	B. D. Sivazlian
Subject:	A Multi-Product Sequencing Problem on a Single Processor Under a Stochastic Environment
Date:	November 8-10, 1972

Joint Meeting of AIIE/ORSA/TIMS
Atlantic City, N.J.
R. L. Francis
Chairman of Sessions on Production Planning and Control, and Location Theory
November 8-10, 1972

Joint Meeting of AIIE/ORSA/TIMS
Atlantic City, N.J.
D. W. Hearn, J. Elzinga and Pl Polyzos
An Implicit Enumeration Algorithm for a Class of Multifacility Location Problems
November 8-10, 1972

Joint Meeting of AIIE/ORSA/TIMS
Atlantic City, N.J.
E. J. Muth
Modeling of Serial Production Systems with Random Service Times
November 8-10, 1972

30th Meeting of Military Operations Research Society
Fort Lee, Virginia
H. D. Ratliff
Optimization of Mine Countermeasures
December 12, 13, 14, 1972

Nonlinear Programming Symposium
George Washington University, Washington, D.C.
D. W. Hearn and W. D. Randolph
A Dual Method for Quadratically Constrained Quadratic Programming
March 14-16, 1973

43rd National Operations Research Society of America Meeting
Milwaukee, Wisconsin
R. L. Francis
A Selective Review of the Location Problem Literature
May 9-11, 1973

31st Meeting of Military Operations Research Society
Annapolis, Maryland
H. D. Ratliff
Chairman of Session on Operations Research in Mine Warfare
June 19-21, 1973

Name of Meeting: ORSA/TIMS Joint National Meeting
Location: Boston, Massachusetts
Author: P. M. Dearing and R. L. Francis
Subject: "A Minimax Location Problem on a Network"
Date: April 23, 1974

Logistics Research Conference
The George Washington University
R. L. Francis
"Recent Analytical Advances in Facility Layout and Location: A Survey"
May 10, 1974

ORSA/TIMS Joint National Meeting
Boston, Massachusetts
D. W. Hearn and Albert Chan
"A Weighted Round Table Trip Location Problem"
April 23, 1974

ORSA/TIMS Joint National Meeting
Boston, Massachusetts
E. J. Muth and P. D. Mehta
"On the Reversibility of Production Lines"
April 23, 1974

Conference on Reliability and Fault Tree Analysis
University of California, Berkeley
E. J. Muth
(no paper given)
September 3-7, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
Donald W. Hearn and W. D. Randolph
Properties of a Generalized Inverse Dual
October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
Donald W. Hearn
Chairman of Session on Management Information Systems
October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
H. Donald Ratliff
Chairman of Session on Network Applications
October 16 - 18, 1974

Name of Meeting:	Joint ORSA/TIMS Meeting
Location	San Juan, Puerto Rico
Author	L. A. Martin-Vega and H. Donald Ratliff
Subject	Scheduling Vehicles Loads Under Certain Fixed Routing Assumptions
Date	October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
Michael E. Thomas
Chairman of Session on Panel Discussion: Should OR/MS Programs be Updated
October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
Robert L. Papineau and Richard L. Francis
A Minimax Facility Layout Problem
October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
Richard L. Francis
Program Chairman
October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
Albert W. Chan and Richard L. Francis
A Round - Trip Location Problem on a Tree Graph
October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
B. D. Sivazlian
A Sequential Replenishment Policy in the Inventory Control of a Perishable Commodity
October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
B. D. Sivazlian
Replacement Theory - Current and Future Direction
October 16 - 18, 1974

Name of Meeting: Joint ORSA/TIMS Meeting
Location: San Juan, Puerto Rico
Author: Thom J. Hodgson, Kerry E. Kilpatrick, and Ira Longini
Subject: An Integer Quadratic Programming Approach for the Scheduling of an Outpatient Clinic System
Date: October 16 - 18, 1974

Joint ORSA/TIMS Meeting
San Juan, Puerto Rico
Thom J. Hodgson
Chairman of Session on Round Table Discussion:
Applications in Production Control
October 16 - 18, 1974